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APPLICATION OF GENETIC ALGORITHM TO THE TECHNOLOGICAL OPERATIONS SCHEDULING PROBLEM

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The basic enterprise task is to satisfy customer requirements: due date, price and quality. Based on experiences from engineers practice of work in Croatian enterprises it could be concluded that enterprises are not able to fulfil obligations to the customer in a way of due dates. One of the basic reasons lies in inappropriate scheduling model that has not had possibility to make plan variants. The paper shows how genetic algorithm could be successfully applied in scheduling model to solve the problem of plan variant. As a basic selection in the paper 3-tournament steady-state selection has been applied.

Key words: artificial intelligence, genetic algorithms, manufacturing, scheduling

Primjena genetičkih algoritma kod problema raspoređivanja tehnoloških operacija. Danas je osnovni zadatak poduzeća zadovoljiti kupčeva zahtjeve u pogledu roka isporuke, cijene i kvalitete. Na osnovi iskustava inženjerske prakse iz hrvatskih proizvodnih poduzeća može se zaključiti kako poduzeća nisu u mogućnosti ispuniti obveze prema krajnjem kupcu u pogledu roka isporuke. Jedan od osnovnih razloga za takva odstupanja leži u neadekvatnom modelu raspoređivanja koji nemaju mogućnost izrade varijanti planova. U radu je prikazana mogućnost primjene genetičkog algoritma kod problema raspoređivanja tehnoloških operacija u svrhu dobivanje viševarijantnog raspoređivanja. Primijenjeni genetički algoritam baziran je na 3-turnirskoj eliminacijskoj selekciji bez duplikata.

Ključne riječi: umjetna inteligencija, genetički algoritmi, proizvodnja, raspoređivanje

INTRODUCTION

The experience from single production shows a delay as the result of complexity of production conditions. The influence of number of factors in production causes significant deviation of due dates which leads to unplanned additional work and higher production costs. The main reasons for these deviations are non adequate planning and scheduling model, unforeseen influence of faults in material; interoperation times are not defined properly; priority rules and launching model [1,2].

To make the right decision, the management must have reliable and complete information and adequate priority rules and scheduling models. Single and small scale productions are characterised by many work orders. So, the application of new tools based on artificial intelligence not only in production process but also in determination of priority of technological operations will be appropriate. Project researchers that were funded by Croatian Ministry of Science and Technology (Development of the MIS of manufacturing companies (152001),

Production Management Planning System (00-35) and Expert system for process planning in the single production (152014)) and the investigation processes [2-7] show a number of programme packages for single production or production that has project character and which are based on net methods and techniques. There are many programme systems applicable to serial production that is based on MRP, MRP II and JIT methodology till the level of technological operations and production capacities. Through the analysis process the following can be concluded. There is no real connection between the project level of single production and term plans of production elements with the main goal to fulfil and reach the dates that were set by Sales department and automatically get production plans and/or purchasing plans for goods, and terms for part production, assembly and cooperation.

For that purpose a number of priority rule algorithms were developed. Through these rules the schedule of production operations on production capacities was made. It takes into consideration the sequence of operation and/or duration of operations. The samples of rules are: according to the way of incoming operations [9], duration [10, 11], due dates [12], percentage of finished jobs [10], queuing [10], dynamic priorities [13] etc. Some of the rules include application of artificial intelligence tools (genetic algorithm, neural networks, fuzzy

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logic and expert systems) for solving scheduling problem [1, 14-18].

ARTIFICIAL INTELLIGENCE AND GENETIC ALGORITHMS

Artificial intelligence pursues the problem of intelligent machine behaviour and tries to find the answer how to create a machine that behaves in such way that could be defined as intelligent. The result of artificial intelligence is the intelligent system that is capable of adaptation, conclusion, decision making, recognition and learning.

Beside finding solutions to the mentioned problem, artificial intelligence algorithms must often satisfy one or more of the following characteristics of intelligent systems [19]: exhibit adaptive goal-orientated behaviour, learn form experience, use vast amount of knowledge, exhibit self-awareness, interact with humans by using language and speech, tolerate error and ambiguity in communications and respond in real time.

The artificial intelligence methods can be divided into: data mining; natural language; voice recognition; robotics; pattern recognition; decision support system; expert system and soft computing (neural networks, genetic algorithms, fuzzy logic).

Genetic algorithms are an optimization methodology based on a direct analogy to Darwinian natural selection and mutations in biological reproduction. In principle, genetic algorithms encode a parallel search through concept space, with each process attempting coarse-grain hill climbing. Instances of a concept correspond to individuals of the species. Induced changes and recombinations of these concepts were compared to an evaluation function to see which ones will survive in the next generation. The use of genetic algorithms requires five components:

1. A way of encoding solutions to the problem - fixed length string of symbols.
2. An evaluation function that gives a rating for each solution.
3. A way of initializing a range of solutions.
4. Operators that may be applied to parents when they reproduce to alter their genetic composition such as crossover (i.e., exchanging a randomly selected segment between parents), mutation (i.e., gene modification), and other domain specific operators.
5. Parameter setting for the algorithm, the operators, and so forth.

PROPOSAL OF GENETIC ALGORITHMS MODEL OF TECHNOLOGICAL OPERATIONS SCHEDULING PROBLEM

The main goal of suggested genetic algorithm model is reduction of manufacturing time through the application of genetic algorithms (population size, selection types, crossover and mutation factors, stopping conditions) and technological and non-technological parameters (due dates, setup time, machining time, number of pieces, price of product, machine availability, starting manufacturing date) which will allow efficient dynamic scheduling and term plan variants. The problem is to find sub-optimal or near optimum order of operation in production because it can be very hard to find the optimal solution in real time.

At the beginning the chromosome has to be defined. Two things have to be emphasized and that are phenotype and genotype. Phenotype represents an original problem object context (plan variant). Genotype is a code or chromosome which is an organic information carrier and contains the exact characteristics of an original object. The chromosome contains information about solution which it represents. Encoding of chromosomes is one of the problems and depends on the problem. There are several ways of chromosome encoding: binary, permutation, value and tree encoding. In this paper permutation encoding which is useful for ordering problems was chosen.

The 3-tournament steady-state selection genetic algorithm without duplicates is chosen. Three different chromosomes will be chosen from the population and after that the worst chromosome will be eliminated according to fitness function. It means that two best chromosomes will be protected from elimination. The reasons for that are: intensive application of genetic algorithm for order problems; elimination selection is faster than generation selection. There are no inter population of chromosomes and elitism is inherently involved in elimination selection; rank selection requires classification of chromosomes according to value of fitness function. Tournament selection makes selection only on the part of population and depends on the position of chromosome in the order of chromosomes towards fitness function. According to the number of chromosomes that are involved in tournament it could be 2-tournament, 3-tournament etc.

The selection gives a higher chance to the better chromosome to survive and to become parents so the whole population is moving towards higher fitness function solutions. Fitness function has to minimise production time and takes into consideration: realised time, due dates, setup time, machining time, number of pieces, price of product, machines availability, starting manufacturing date and weight factors (which have to emphasize due date in comparison with product price). Genetic algorithm parameters: crossover factor, mutation factor, inversion factor, conditions to stop genetic algorithm are inherently implemented in the programme source code which is done in combination of C and C++. Initial population is stochastic. Mutation rate was 0,1%. Crossover probability was uniform. The result of genetic algorithm is term plan variant.

The proposed model has several restrictions:

1. During the analysis process new jobs will not be taken into consideration.
2. Operation order is defined through the technological procedures.
3. Interoperation losses are not taken into consideration.
4. Operation will be done according to the resource (machine) availability
5. The current operation will be finished. Other operations are going in new calculation together with new jobs.

Figures 1. and 2. show input masks with all parameters that are necessary for genetic algorithm which are not inherent implemented in genetic algorithm. They are: number of products, number of machines, number of technological operations (the highest number that appears for all products), number of desired iterations, population size, price of product, due dates, setup time, machining time, machines availability.

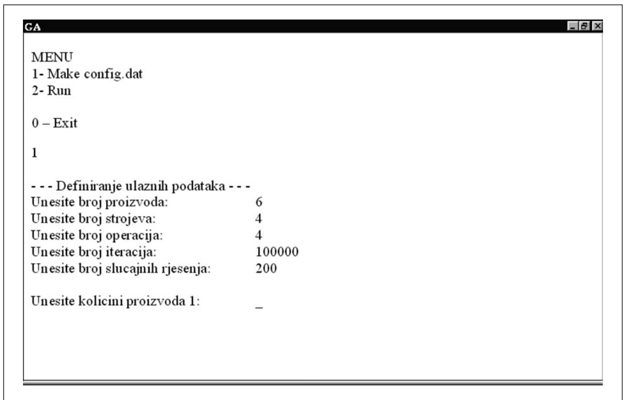

Figure 1. Input mask for definition of config.dat file

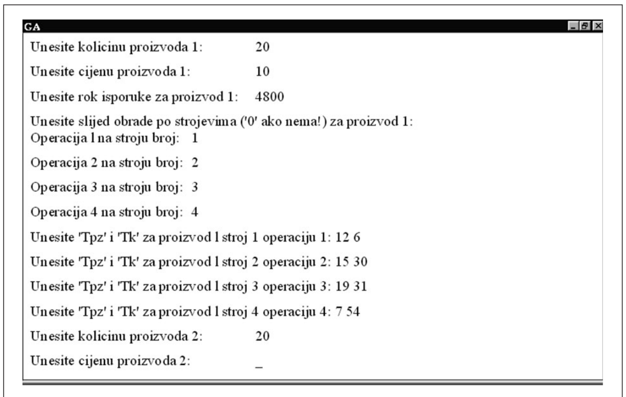

Figure 2. Input mask for definition of config.dat file (continuing)

Through the initialisation process the starting population will be generated usually randomly from the range of possible solutions (plans). The selection of the best chromosome will be done according to the calculation of fitness function. The genetic materials will be transferred through the reproduction process to the next generation, and the worst chromosomes will be eliminated. The next step is the crossover where the attribute will be transferred from parents to children.

The following is mutation that represents random changing of attributes. It means that genes in the chromosome will be changed. In such a way the attributes are improving from generation to generation.

Figure 3. shows the mask after the algorithm was finished. It shows how results can be changed through the iteration process (P-product, O-operation, S- Machine, FD- fitness function). The solution that is last presented is the final solution that is achieved by genetic algorithm.

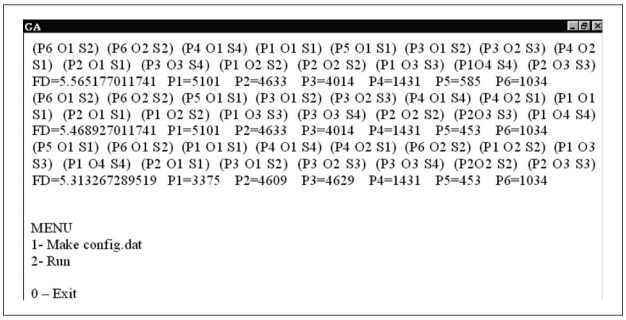

Figure 3. Sub-optimal solution of the problem

Beside genetic algorithm the following priority rules are used: First Come First Served) (FCFS), Earliest Due Date (EDD), minimum Slack (SLACK), Critical Ratio (CR), Shortest Processing Time (SPT), Longest Processing Time (LPT), Work order priority rule (PRN) and Genetic Algorithm (GA).

The PRN priority model [18] was developed as a practical necessity of priority assignment of every work order, which has to be produced. The main difference between PRN priority rule and other rules is that PRN rule involves the number of input parameters (technological and non-technological from financing, accounting and purchasing departments). The variations of specific parameters increase flexibility of a model.

Through the analyses and comparison of experimentally given results [1] it is visible that the best results are acquired by the application of genetic algorithm and work order priority rule.

Based on input data, priority rules define only one possible solution (term plan) from the set of possible solutions. At the same time genetic algorithm searches for more solutions from the set according to conditions that are defined by genetic algorithm suspension.

Genetic algorithm gives "the best solution" (between calculated solutions) which is not the optimal. One disproportion between the best and the worst result acquired by genetic algorithm is shown on Figure 4. It means that each start of genetic algorithm gives different solutions. Hill climbing according to given results is shown in Figure 5.

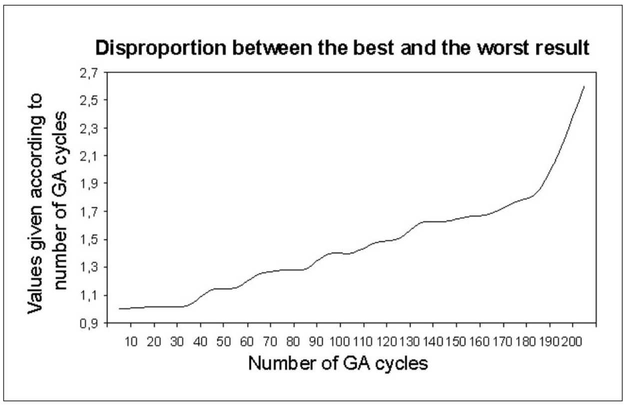

Figure 4. Disproportion between results realised by genetic algorithm

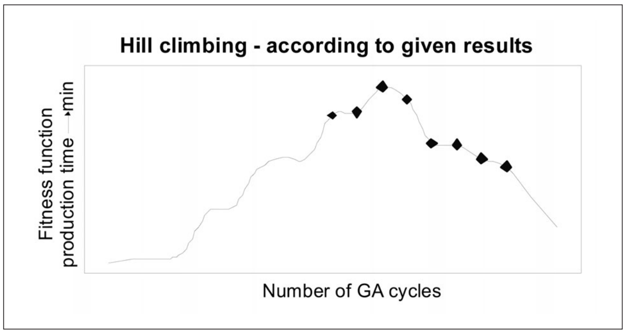

Figure 5. Concentration of given results on high hills - hill climbing

Average reduction of the plan compared to the average delay of the longest plan (LPT rule)) is shown in Figure 6. Solution achieved by genetic algorithm is better than the solutions given by priority rules

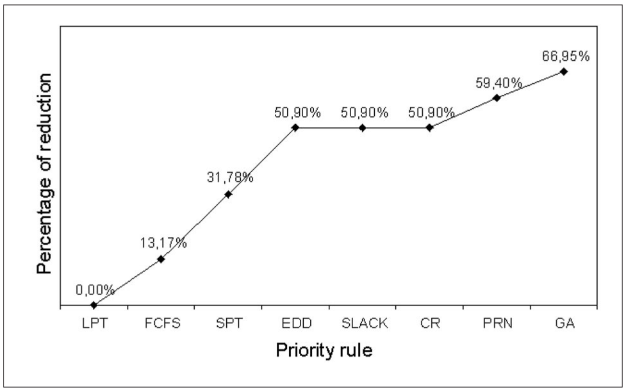

Figure 6. Average decreasing according to average lateness

Integration of a model based on genetic algorithm in Enterprise Resource Planning system

Enterprise Resource Planning (ERP) is a systematic method of dynamical balancing and optimizing of the company resources. When used effectively it can enable a company to achieve world-class results in growth, profitability, and product and service development. It functions within the paradigm that every business is uniquely similar [20].

ERP system has to provide complete integration of all departments and all functions of the enterprise. Better integration of data and processes will improve business process performances. The main ERP system goals are: to decrease preparation and production time, to decrease costs, to provide flexibility according to market demands and to allow better connections and communications during the realisation process.

Figure 7. shows basic ERP functions [21].

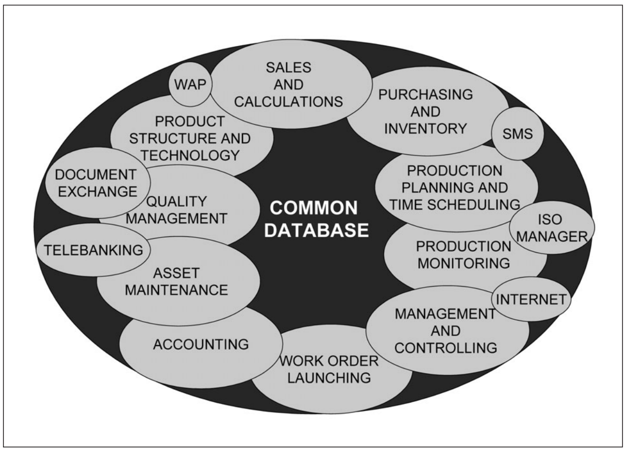

Figure 7. ERP content

To achieve the optimal plan variant, the new methods and algorithms have to be developed. They have to take into consideration deficiency of resources (materials, tools); variation in documentation and technology; dependence on other participators (cooperation in making documentation and production, testing etc); improper technical documentation; special tools have been made parallel with production process; purchasing has to be done according to evaluation and significant differences between necessary and available resources. All these goals overlap more or less which means that a plan is not static category and many times it has to be changed immediately after it has been made. The balance between all these criteria has to be found and many times it is a combination of different requirements.

Figure 8. represents suggested place of genetic algorithm in ERP system and the data that have to be taken from subsystems and transferred directly to genetic algorithm.

CONCLUSION

The paper shows research results that have been done with the main goal to extend the possibility of technological operation scheduling problem. The defined model is based on genetic algorithm. It is necessary to emphasize that realised term plan variant is not optimal but rather sub-optimal. From the results comparison it can be seen that all rules, except genetic algorithm define only one possible solution (term plan). Genetic algorithm compares lot of plans according to fitness func-

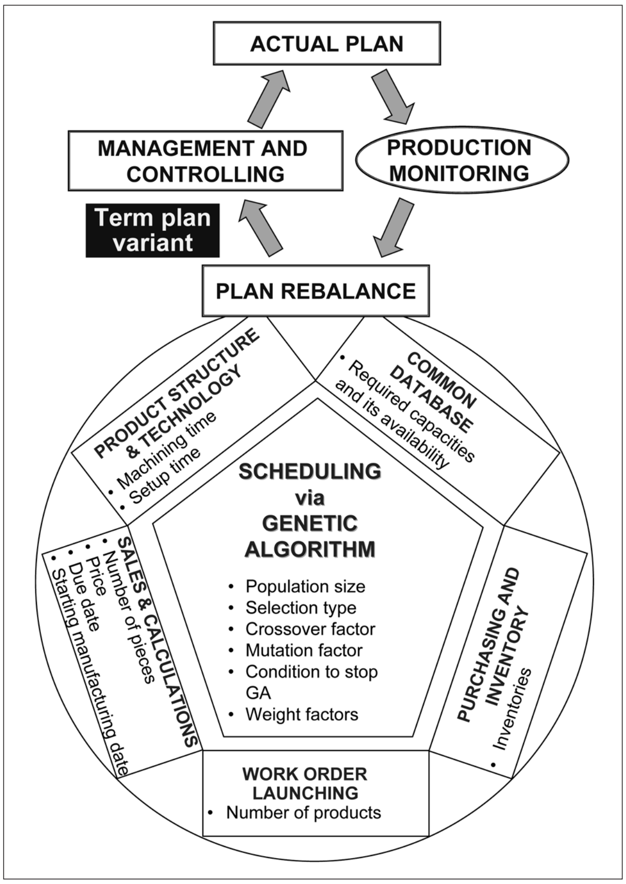

Figure 8. Integration of genetic algorithm model in ERP system

tion and specified number of iterations. Between these solutions it can be expected that some of these solutions have better results than other rules.

The results that are realised through the application of genetic algorithm:

– variant scheduling,
– rationalisation of work of managers and enterprise management,
– rationalisation of capacity utilisation,
– background for a decision making process in a way to make the right decision in the shortest period of time, based not on experience and competence of one but on the real production parameters and the current situation on the market,
– improvement of organisation of production preparation and production departments in enterprises for single and small scale production.

The acquired results encourage and make preconditions for further development and improvement of suggested model and optimisation process especially in a way of: involvement of costs and losses; application of other genetic algorithms and comparison of acquired results and connection of suggested genetic algorithm with neural network and expert system in order to make better and more precise decision.

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